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DOME RESPIROMETER FOR THE MEASUREMENT OF SEDIMENT OXYGEN DEMAND AND PLANT RESPIRATION

- CONSTRUCTION AND USE -

Water Resources Technical Report

Ministry of the Environment
Ontario

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WATER RESOURCES TECHNICAL REPORT

DOME RESPIROMETER FOR THE MEASUREMENT OF SEDIMENT OXYGEN DEMAND AND PLANT RESPIRATION
- CONSTRUCTION AND USE -

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Introduction

In many stream assessment studies, two of the most critical parameters often examined are sediment oxygen demand (SOD) and aquatic macrophyte respiration. These are required in order to assess the dissolved oxygen regime and assimilative capacity of the stream. Accurate measurements of these processes, can be achieved by isolating a small section of the stream substrate and overlying water from the surrounding water column and monitoring its oxygen content. A dome respirometer, suitable for use in shallow rivers, was designed and built by the River Systems Unit, Quality Protection Section, for this purpose. With minor modifications the unit can also be adapted for use in deeper river sections or lake conditions. The unit is light-weight and easily handled by one person, and since prefabricated components are used, material and labour costs are minimal.

Principle of Operation

The respirometer encloses a known volume of water over a known cross-sectional area of sediment. A dissolved oxygen (DO) probe attacned to a recording DO meter is inserted through a port at the side of the respirometer. The water in the chamber is constantly stirred to provide fresh water over the sediment surface and to avoid oxygen depletion in the vicinity of the oxygen electrode. This ensures a uniform reduction in the DO concentration. As chemical and biological processes in the substrate consume oxygen, the DO concentration decreases in the water within the dome. A light and a dark bottle containing ambient water are suspended and monitored in parallel with the respirometer to provide a measure of photosynthetic oxygen production and background respiration. Placement of substrate pans on the stream bottom allows for the calculation of macrophyte respiration once the pans have been colonized by an active plant community. The respirometer is left in place for a period of time (at least 2-4 hrs) to allow for a reduction rate to be established unequivocally. Simple calculations convert the oxygen change to oxygen demand on a unit areal basis after correction for respiration and chemical oxygen demand causing

oxygen uptake within the entrained water volume is applied. The oxygen uptake rate of a particular sediment depends upon several factors, including physical conditions. Chemical and biological factors which influence the dissolved oxygen uptake include the indigenous bacterial, algal and macrophyte communities, nutrient concentrations in the sediment and water, and the presence of chemical reducing agents (i.e. bacterial by-products such as sulphide). The temperature of and the dissolved oxygen concentration in the water also affect the oxygen demand rate.

Construction

The version of the dome respirometer used to measure sediment oxygen demand is constructed from prefabricated materials to minimize material and labour costs. A plexiglass hemisphere of 24.8 cm inside radius, with 0.5 cm wall thickness, was used to form the respirometer housing. It was found that hemispherical skylight domes are ideal for this purpose. When the domes are manufactured, the mold used to shape them leaves a horizontal flange, which is useful in forming the respirometer housing and which lends additional rigidity to the unit. A vertical flange, constructed from 22 gauge stainless steel by a metal fabricator (Figure 1), is sealed to the dome using silicone sealant and then rivetted to both the dome and the horizontal flange (Figure 2). This provides rigidity to the unit and ensures a water-tight seal between the dome and the flange. Internal circulation of water in the respirometer is provided by a submersible six volt bilge pump (available from marine suppliers), attached to the upper interior surface of the dome (Figure 3A) and directed towards the dissolved oxygen probe. A purging vent and rubber stopper (No 7) are placed at the top of the dome to facilitate removal of entrapped air bubbles during placement of the respirometer in the stream.

A second version of the respirometer was designed for use in aquatic plant respiration studies. In this version, the horizontal flange is trimmed from the dome, and the vertical flange replaced by a rubber gasket which is fastened to the outside edge of the dome (Figure 3B).

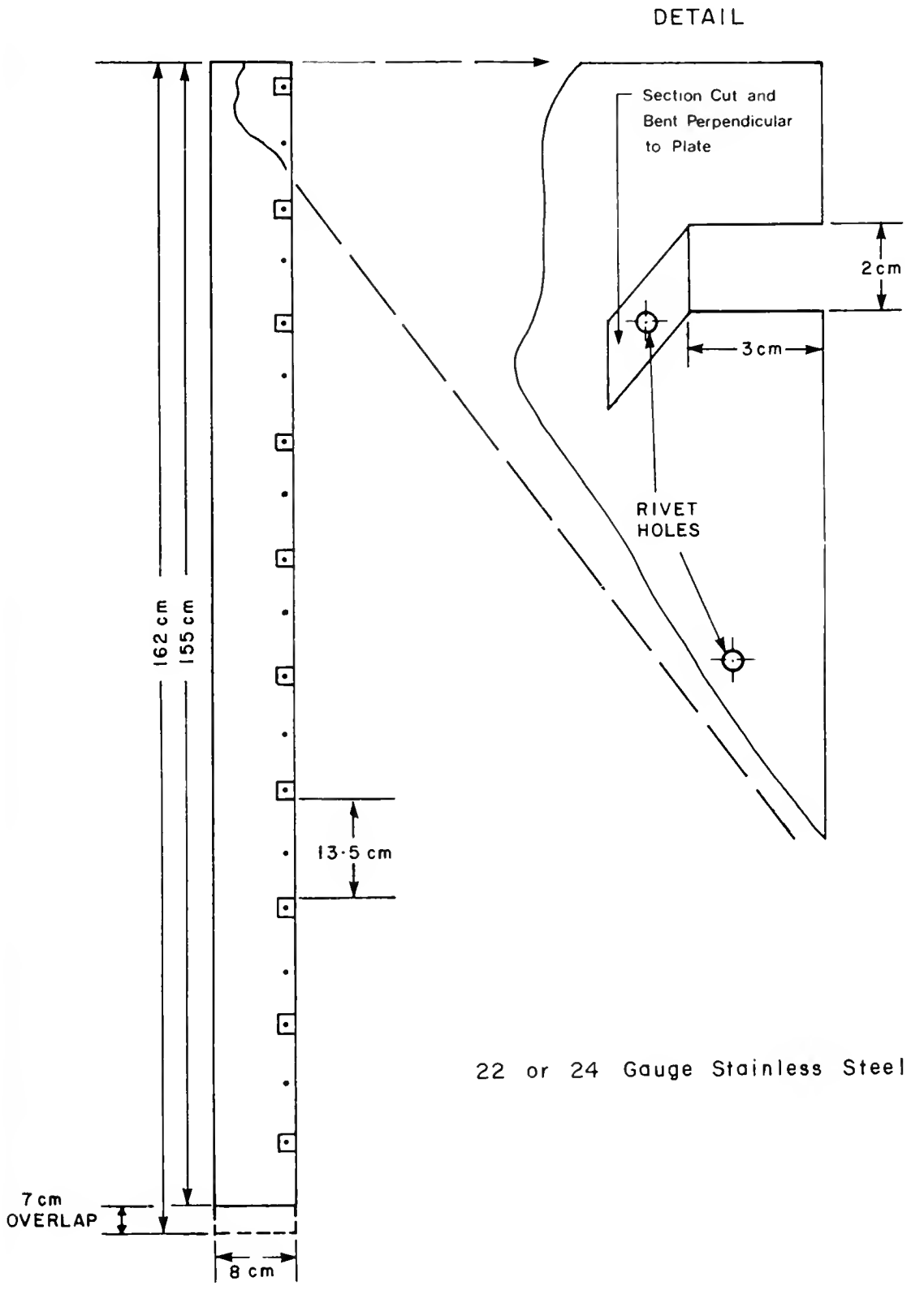


FIGURE 1: SEDIMENT DOME RESPIROMETER – PLAN FOR VERTICAL FLANGE

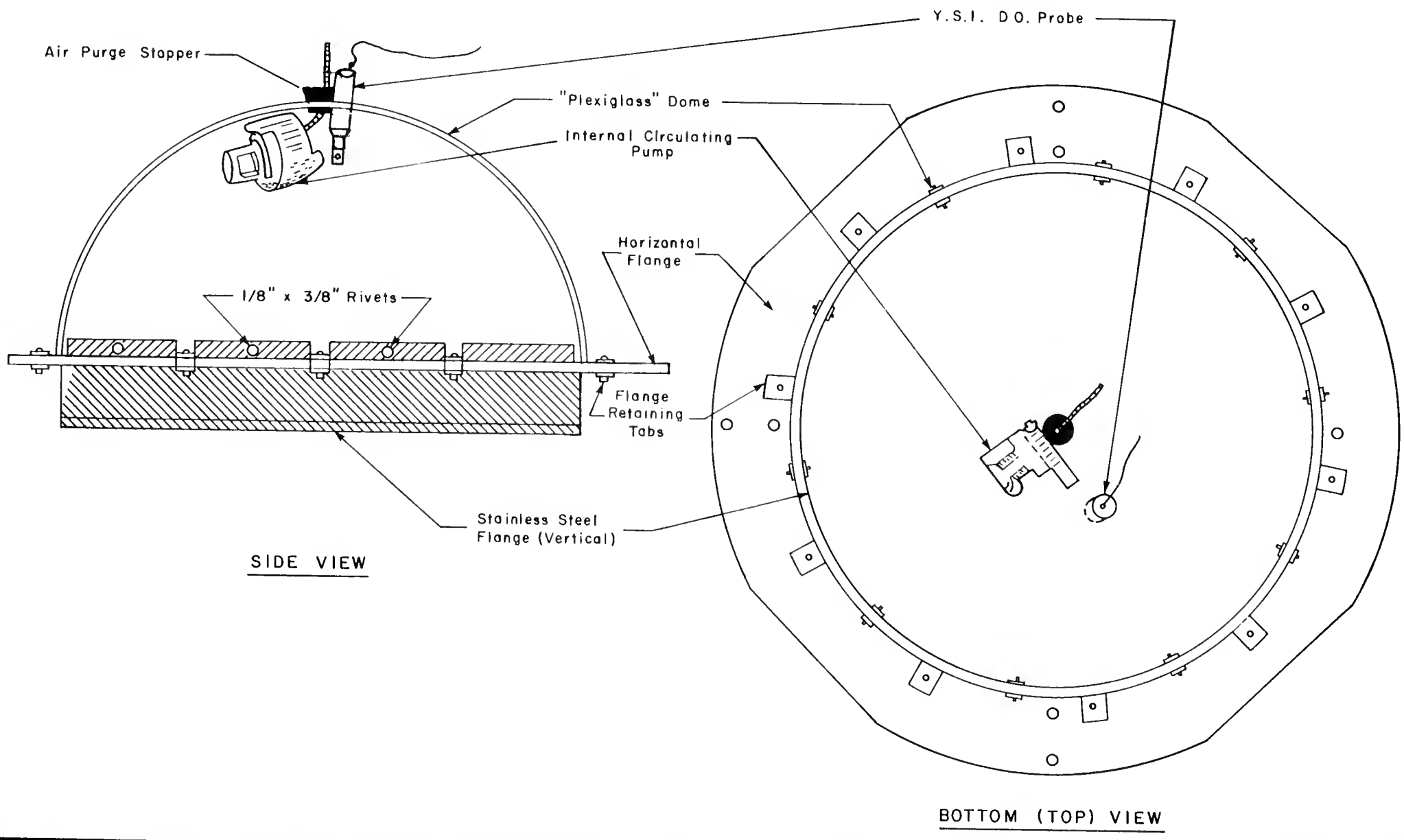
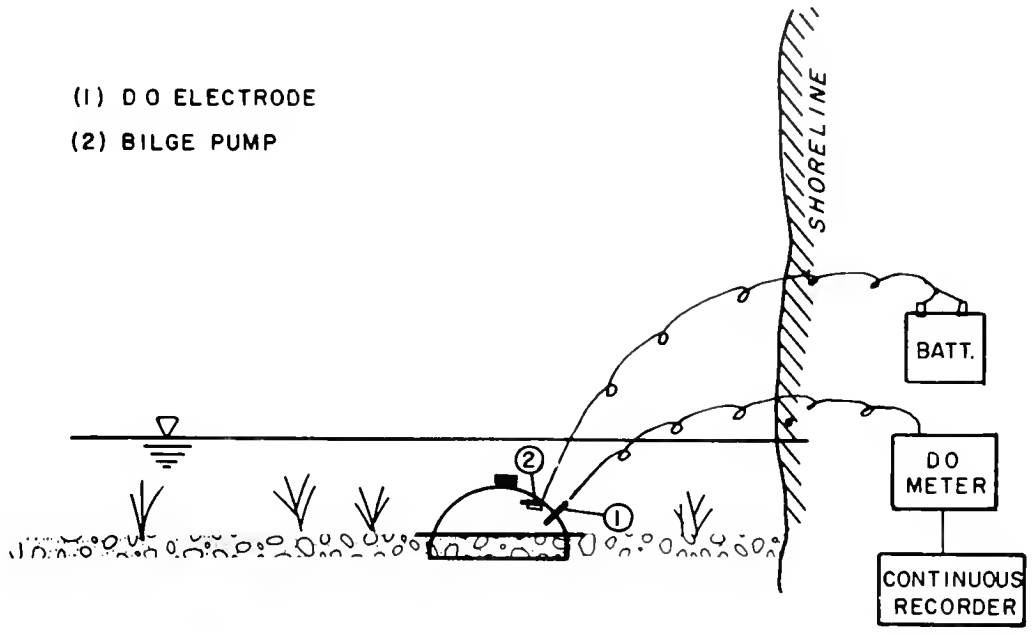


FIGURE 2 : DOME SEDIMENT RESPIROMETER DETAIL

A: SEDIMENT DOME



B: PLANT DOME WITH SUBSTRATE PAN

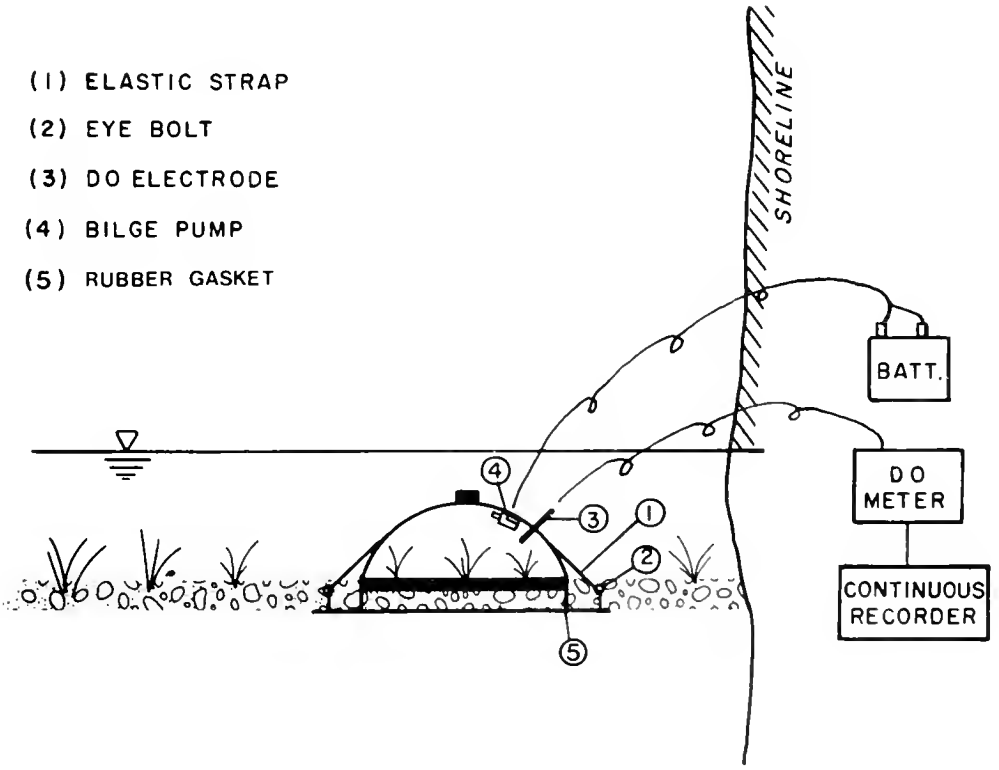
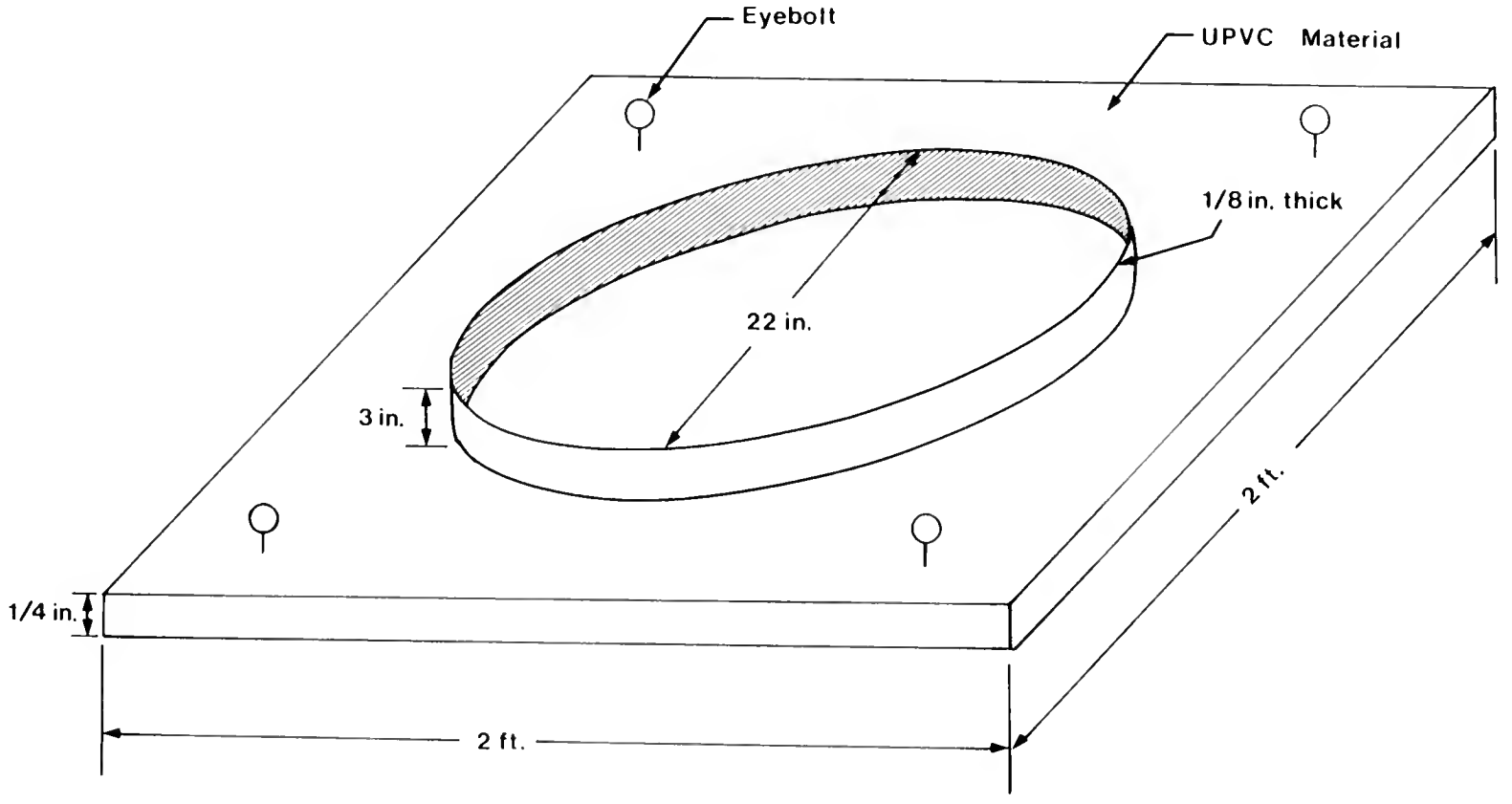


FIGURE 3 : SCHEMATIC OF DOME RESPIROMETER SETUP



Note: The Dome is attached to the substrate pan by means of elastic straps fastened to the eyebolts.

FIGURE 4: SUBSTRATE PAN

The substrate pan (Figure 4) is constructed of unchlorinated polyvinyl chloride (UPVC) material. This base is 0.6 m square and 0.6 cm thick, and the vertical flange is 55 cm in diameter, 7.6 cm high and 0.3 cm thick, and fits inside the dome.

It is also possible to construct a respirometer without drilling holes in the plastic dome (Figure 5).The wires for the DO electrode and stirrer-motor may be introduced through a slit in the vertical stainless steel flange with another small piece of stainless steel material bolted over the slit. A stainless steel ring may be fixed with epoxy resin glue to the inner top surface of the plastic dome to provide an attachment point for the electrode and stirrer. Such a system was used by the Ministry of The Environment, Lake Systems Unit, in deep-water measurements in Hamilton Harbour.

Dark domes required in light/dark dome photosynthesis-respiration studies can be fabricated either by using black plexiglass for the dome material or by painting the inside of the domes with black paint. When a dark dome is used, a dark bottle should be used in parallel to monitor water column oxygen demand. Similarly, a clear dome would necessitate the use of a clear or light bottle.

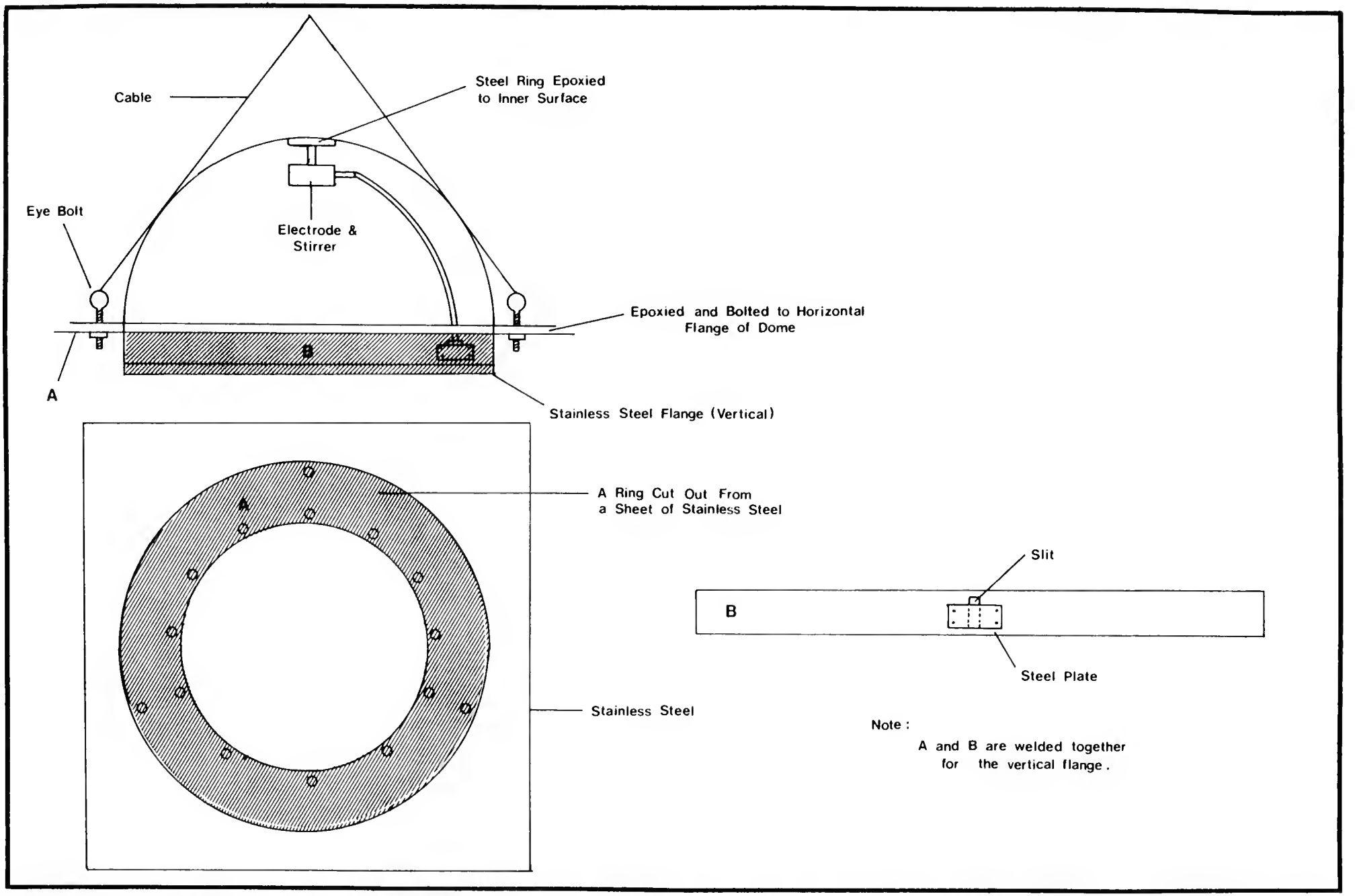


FIGURE 5: DOME RESPIROMETER FOR USE IN DEEP WATER MEASUREMENTS

Materials for Construction

The following is a list of materials required for the construction of a single dome respirometer.

1 - plexiglass hemisphere 24.8 cm radius, by 0.5 cm wall thickness, untrimmed;
1 - stainless steel flange, 22 gauge, 8 cm wide x 165 cm long;
1 - submersible bilge pump (6-12 volt: 250 gal/hr maximum);
10 - 0.3 cm by 0.5 cm rivets;
9 - 0.3 cm by 1.3 cm rivets;
1 - ABS plastic fitting threaded or press fit to match dissolved oxygen probe;
1 - rubber stopper for purge vent, No 7;
15 - metres double lead wires suitable for submarine use;
1 - tube silicone sealant;
1 - tube contact cement;

Approximate Cost = $100.00 (1980 Dollars)

Additional Materials

1 - dissolved oxygen meter and probe
1 - 6 volt battery.

Use of Respirometer

The dome respirometer was designed primarily for ease of use. The following five steps outline the operational procedure:

1. The dissolved oxygen probe is calibrated and inserted into the aperture provided near the top of the dome.
2. The respirometer is lowered to the sediment with the air purge stopper removed. It is embedded into the sediment to the level of the horizontal flange, making sure that a proper seal is obtained. Sites chosen should be generally representative of the bottom sediments in the area of interest.
3. The battery leads are connected and the pump is turned on. After a minute or two the air purge stopper is put into place. This allows air bubbles trapped inside the respirometer to escape.
4. Initial DO readings in the dome and light (or dark) BOD bottle are taken.
5. After a period of time, usually 2-4 hours, the final DO readings are taken and the respirometer is removed. The test duration is variable and depends on the sediment activity; the higher the sediment activity the shorter the duration time of the test and vice versa. The test must end before the DO reaches zero to ensure accurate calculation of the reduction rate, and sufficient time must elapse during the test for a reduction rate to be established clearly.

The plant dome is fitted to the substrate pan by pushing the dome down over the flange until a snug fit against the pan surface is achieved. Rubber retaining straps are fastened between the eyebolts on the dome and the eyebolt on the substrate pan to maintain the fit during the experiment.

A schematic diagram of sediment and plant dome respirometer setups are shown in Figure 3.

Test Results

The dome respirometer was tested in sediment deposits in several river locations. Tests indicate that the device works well, even in areas of low oxygen consumption activity.

The following are measurements made at selected locations. A sample of continuous oxygen uptake recording is shown in Figure 6.

Table 1: Test Results Using Sediment Dome

LOCATION	DATE	SOD (gm O_2/m^2/day)	TEST DURATION (hrs)	MEAN AMBIENT TEMPERATURE (^oC)
Speed River				
	29 June/76	5.56	4.25	-
	7 July/76	2.90	2.50	24.75
	8 July/76	3.09	2.75	24.0
	13 July/76	2.03	3.60	21.15
	28 July/76	0.89	2.50	24.25
Speed River				
	22 July/76	3.45	3.02	26.0
Humber River at MOE Lab	18 July/76	1.65	5.0	-
Speed River at Preston	4 July/80	2.35	3.5	18.5

Calculations

1. Calculation of volume and area of respirometer:

   inside diameter = 49.3 cm

   volume of hemisphere = 31.82 litres (minus pump and probe head = 31.5 litres)

2. Active cross-sectional area of respirometer = 0.193 m^2

SPEED RIVER AT PRESTON

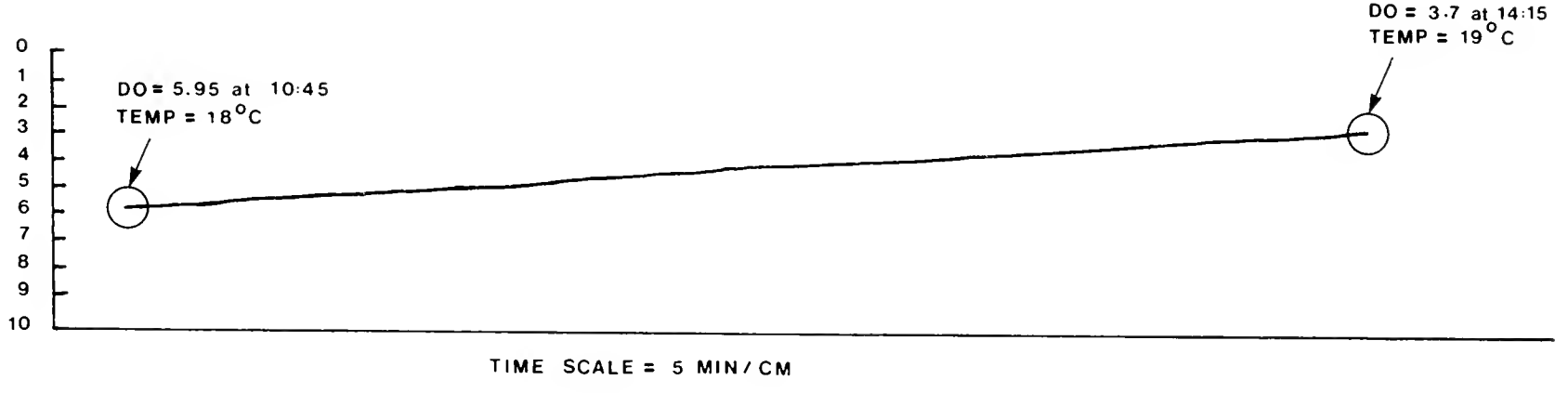


FIGURE 6: CONTINUOUS OXYGEN UPTAKE RECORDING

3. Calculation of oxygen uptake rate

$$SOD = (TOD - WCOD)\ \frac{mg}{L} \cdot 31.5\ \text{litres} \cdot \frac{1\ gm}{1000\ mg} \cdot \frac{1}{0.193 m^2} \cdot \frac{24\ hrs}{1\ day} \cdot \frac{1}{T\ hrs}$$

$$= \frac{TOD - WCOD}{T} \cdot 3.922\ gm/m^2/day$$

where: SOD = sediment oxygen demand
WCOD = water column oxygen demand
TOD = total oxygen demand (sediment + water column)
T = duration of test

4. Sample calculation: (See Table 1 and Figure 6: Speed River at Preston, July 4, 1980)

T = 3.5 hrs
TOD = 2.25 mg/L (from Figure 6)
WCOD = 0.15 mg/L (from field BOD bottle)

$$SOD = \frac{2.25 - 0.15}{3.5} \cdot 3.922\ gm/m^2/day$$

$$= 2.35\ gm/m^2/day$$